FINAL REPORT

Grant #: N00014-95-1-1058

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GRANT TITLE: Buoyancy Regulation and the Energetics of Diving in Dolphins, Seals, Sea Lions and Sea Otters

REPORTING PERIOD: 1 May 1996 - 30 April 1998

AWARD PERIOD: 1 May 1995 - 30 April 1998

OBJECTIVE: A comparative assessment of the role of buoyancy regulation in diving mammals.

APPROACH: The swimming and diving characteristics of northern elephant seals and New Zealand sea lions in nature were examined. Swim speed, ascent and descent rates were measured using data loggers attached to the animals in order to compare differences in diving behavior. Differences in diving behavior were compared to the predictions of buoyancy regulation models. These models make predictions whether an animal should use hydrostatic or hydrodynamic buoyancy regulation based on their body size and swimming speed. In a separate study we experimentally examined the relationship between buoyancy and diving behavior in juvenile northern elephant seals. The seals were divided into three treatments: seals that would be made more buoyant (B+), seals that were to be made less buoyant (B-), and control seals (Bc). Their buoyancy was modified through the addition of noncompressible syntactic foam discs (B+) or lead weights (B-) placed inside PVC tubes. Time-depth recorders and the PVC buoyancy tubes were attached to the seals, and they were released in Monterey Bay. The seals returned to Año Nuevo after several days, and the instruments were recovered and the diving data analyzed.

ACCOMPLISHMENTS: The swimming patterns of elephant seals and sea lions fit the predictions of buoyancy models. Given their size and swim speed elephant seals rely primarily on hydrostatic buoyancy, whereas due to the smaller size and faster swimming speeds, sea lions benefit from hydrodynamic buoyancy regulation. We found that the density and therefore buoyancy of adult female elephant seals varies over their long migration trips to sea. Modifications of buoyancy in

juvenile elephant seals only effect descent rate. Seals descended more rapidly when they were less buoyant.

SIGNIFICANCE: This study demonstrated that buoyancy plays a significant role in shaping the diving behavior of seals and sea lions. We found that marine mammals either use either hydrostatic or hydrodynamic buoyancy regulation depending upon their swimming speed and diving strategy. True seals rely more on hydrostatic buoyancy regulation, while sea lions, fur seals and cetaceans rely more on hydrodynamic buoyancy regulation.

PUBLICATIONS AND ABSTRACTS:

Crocker, D.E., Gales, N.J. and Costa, D.P. 1999. Swimming speed and foraging strategies of New Zealand sea lions, *Phocarctos hookeri*. Functional Ecology in review.

Blackwell, S.B. Haverl, C.A. LeBoeuf, B.J. and Costa, D.P. 1999. A method for calibrating swim speed recorders. Marine Mammal Science in press.

Costa, D.P., and Williams, T.E. 1999. Marine mammal energetics. In: *The Biology of Marine Mammals*, ed. J. Reynolds and J. Twiss. Smithsonian Institution Press. Washington, DC. in press.

LeBoeuf, B.J., Crocker, D.E., Costa, D.P., Blackwell, S.B., Webb, P.M. and Houser, D.S. 1999. Foraging ecology of northern elephant seals. Ecological Monographs in press.

Webb, P.M. 1999. Effects of Buoyancy and Body Composition on the Diving Behavior and Swimming Effort of Northern Elephant Seals, *Mirounga angustirostris*. Ph.D. Dissertation University of California Santa Cruz. 136 pages.

Webb, P.M., Crocker, D.E., Blackwell, S.B., Costa, D.P. and LeBoeuf, B.J. 1998. Effects of buoyancy on the diving behavior of northern elephant seals. Journal of Experimental Biology 201: 2349-2358.

Costa, D.P., Gales, N.J. and Crocker, D.E. 1998. Blood volume and diving ability of the New Zealand sea lion, *Phocarctos hookeri*. Physiological Zoology 71:208-213.

Webb, P.M., Andrews, R.D., Costa, D.P., and LeBoeuf, B.J. 1998. Heart rate and oxygen consumption, of northern elephant seals during diving in the laboratory. Physiological Zoology 71:116-125.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	24 June 1999	Final Report

4. TITLE AND SUBTITLE

Buoyancy Regulation and the Energetics of Diving in Dolphins Seals, Sea Lions and Sea Otters.

5. FUNDING NUMBERS

N00014-95-1-1058

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
800 N. Quincy St
Arlington, VA. 22217-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

We examined swim speed and ascent descent rates in sea lions and elephant seals in order to make comparisons in their diving strategies and how these may be effected by different strategies of buoyancy regulation. We experimentally examined the relationship between buoyancy and diving behavior in Juvenile northern elephant seals. This study demonstrated that buoyancy plays a significant role in shaping the diving behavior of seals and sea lions. We found that marine mammals either use either hydrostatic or hydrodynamic buoyancy regulation depending upon their swimming speed and diving strategy. True seals rely more on hydrostatic buoyancy regulation, while sea lions, fur seals and cetaceans rely more on hydrodynamic buoyancy regulation.

14. SUBJECT TERMS

Buoyancy regulation, diving behavior, swim speed, seals, sea lio

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL